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ALCOHOLIC EXTRACTION OF OIL FROM SOYBEANS [1]

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The development of a process at this Laboratory for the extraction of soybean oil with ethyl alcohol (grain alcohol) as a solvent stemmed from the original conviction of Dr. A. K. Smith (in charge of the Protein Section) that the influence of the solvent on both oil and meal is of considerable importance. This concern of the Protein Section arises from the fact that isolated soybean protein finds many industrial uses where the color standard is dictated by casein from milk. Casein is a light-colored product and as such has had a slight advantage over protein isolated from hexane flakes. Dr. Smith was convinced that the "off color" of the soybean protein was not due to the protein itself but to coloring matter derived from the flaked beans. It seemed possible that the proper choice of solvent for oil extraction might assist in the solution of the problem.

It was evident from the literature that no systematic study of the effect of the solvent had ever been carried out. As a result, a study of the effects of certain solvents was undertaken. The solvents investigated were: carbon tetrachloride, trichlorethylene, ethylene dichloride; isobutyl alcohol, isopropyl alcohol, ethyl alcohol, and hexane. It was found that the solvents as such probably do not alter the oil or protein significantly, but they produce effects on the products because of dissolution of minor constituents of the bean which accompany the oil or, conversely, are left in the meal to interfere with the uses to which those products are put.

It is developed from the study of the influence of the several solvents that ethyl alcohol (ordinary "drinking" alcohol--denatured, incidentally) produced lighter colored meal than any other solvent; further, it was possible to produce the lightest colored isolated protein from this meal.

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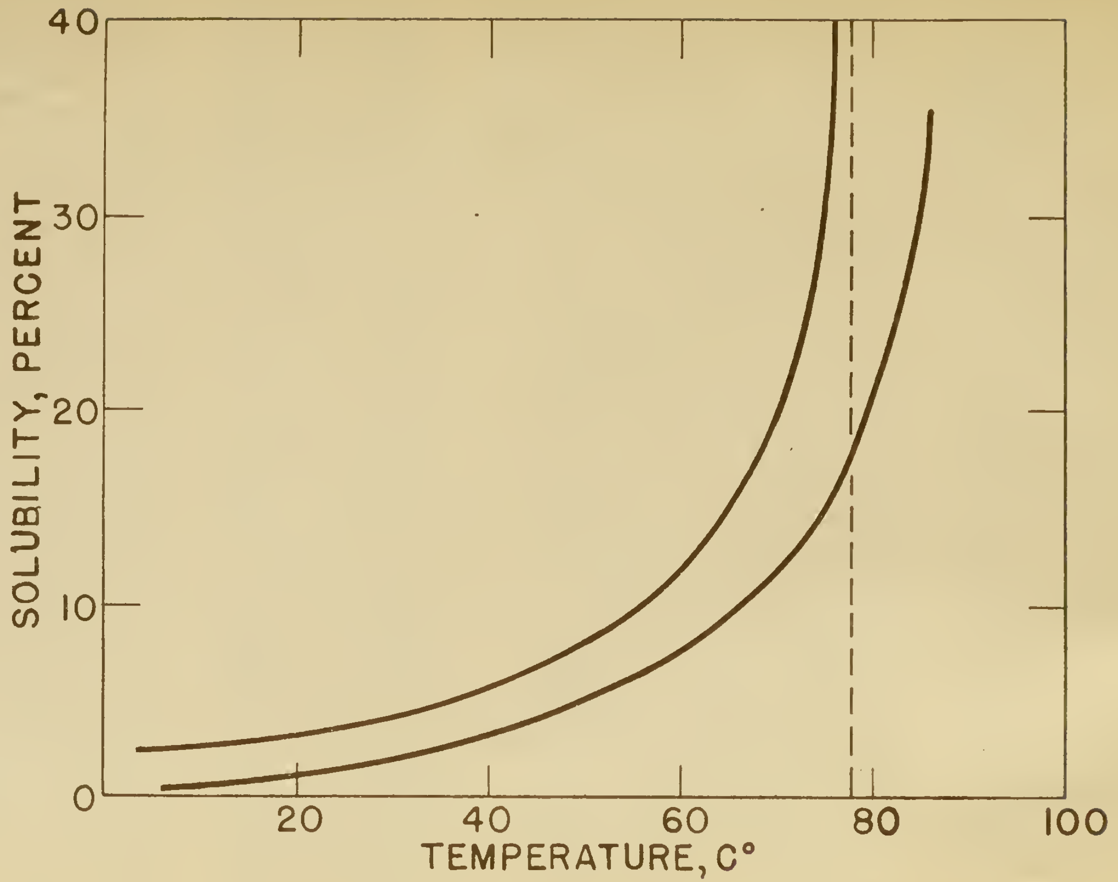
Then it was discovered that this alcohol-extracted meal contained less of the beany and bitter principles present in the bean than any of the other meals; furthermore, the oil needed less refining because the free fatty acid content was less than one-fifth that of the usual commercial oil and the amount of "break" material to be removed by water washing was very low.

There is a very interesting reason why ethyl alcohol produces these effects. These nonoil and nonprotein materials, which also include sterols, saponins, other bitter principles, and coloring matter, all exist in the plant itself largely in the form of glucosides. A glucoside is a combination of a substance with a sugar-like material. These combinations are soluble or dispersible in water and thus are carried in the sap. Ethyl alcohol is the best solvent for these substances and also is a good solvent for the oil. Wood alcohol is a fine solvent for these undesirables but has very poor oil-dissolving properties. Isopropyl alcohol is a better oil solvent than ethyl alcohol but is not as good for removing the impurities from the meal, particularly the bad-tasting materials. Therefore, it appeared most profitable to study the use of ethyl alcohol for the extraction of soybean oil.

I shall not spend much time on the historical aspect of the use of ethyl alcohol but shall proceed shortly with a description of the process developed at the Northern Regional Research Laboratory. It will suffice to say that the Japanese had developed a batch-alcohol process to a semi-commercial scale and that the Germans had several processes which involved the addition of varying amounts of other solvents to the alcohol. All of these investigators had recognized the superior quality of the products resulting when ethyl alcohol is used as solvent but none of them had developed a process which could compete economically with the hexane extraction process.

The fact that the use of ethyl alcohol as a solvent can produce an improved oil and at the same time an improved meal may be made somewhat clearer by the accompanying diagram which shows the solubility of the oil in alcohol at various temperatures. The vertical distance represents the solubility of the oil, the horizontal distance represents the temperature. The first curved lines shows the solubility of soybean oil in absolute alcohol at the various temperatures. Since the dotted line represents the boiling point of the alcohol, it is evident that before the boiling point is reached the oil is completely soluble in alcohol in all proportions. Applying this information to the use of this type of alcohol in the extraction of soybean oil it may be seen that if the extraction is carried out at or near the boiling point, the oil in the flakes will be almost completely dissolved. If the resulting solution is removed from the flaked meal at this temperature and allowed to cool in a separate vessel, the decrease in temperature and the decrease in the solubility of the oil will cause the major portion of the oil to separate from the alcohol solution. In fact, if the cooling is allowed to go to room temperature, the percentage of oil left in the alcohol will be about 3 percent. The other materials dissolved from the flaked bean by the alcohol do not have this same solubility-temperature relationship and, therefore, they remain in the alcohol.



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At this point the net result has been the removal of the oil and impurities from the soybean, leaving an improved meal, and the separation of a relatively pure oil from the alcohol solution. This is the point to which I referred previously when pointing out that both an improved flake and an improved oil could be produced at the same time by the one solvent, alcohol. The same situation exists when 95 percent alcohol is used, as is shown in the second curve of the diagram. To obtain high solubility it is necessary when this alcohol is used to heat the solvent above the boiling point at atmospheric pressure. This is accomplished by carrying out the process under a small amount of pressure (15 pounds is sufficient). The separation of the hot solution from the flakes must also be carried out under pressure.

It may also be noted from the diagram that on cooling to room temperature the 95 percent alcohol retains less oil than does the absolute alcohol. The information up to this point has been known for a long time, and was the starting point for the investigations at this Laboratory. Now, if the recovery of the oil and the recovery of solvent alcohol was to be carried out in the same way that hexane is recovered in the usual extraction process--that is, by distillation--it would be necessary to use 2 1/2 times as much heat energy to distil the alcohol as is required to distil hexane. Furthermore, when the alcohol containing the nonoil solubles is distilled a dark caramelized tar-like material is formed which adheres to the sides of the still and is difficult to remove. This also causes a loss of substances which may be of considerable value. Such a process is decidedly uneconomical.

Then came the discovery at this Laboratory that it is possible to devise a process in which no distillation is necessary. We found that if the alcoholic solution remaining after the separation of the oil is cooled a further small amount, a considerable portion of the nonoil solubles separate in a semisolid condition. There is left a brilliantly clear alcohol which contains between 4 and 5 percent of soluble material. This content is dependent on the temperature reached in the second cooling stage. (Cold water at 55° to 60° F. is sufficient.)

One more step is necessary to complete the nondistillation process. This is the prevention of absorption of water from the soybean flakes by the alcohol. It is accomplished through the simple procedure of drying the flakes to 3 percent moisture or less before solvent extraction. It had been found that flakes of this moisture content did not loose water to the alcohol, but in the course of the usual process usually removed water from the alcohol leaving it a better solvent than when first used. We have carried out these steps just outlined and have reused the alcohol 85 times without ever having distilled it. As we have just said, the alcohol was a better oil solvent at that time than it was at the beginning of the experiment. The oil content of the flakes was always reduced to less than 1 percent, and the amount of semisolid material obtained in the second cooling amounted to about 2 1/2 percent of the original bean.

To recapitulate: The steps required after the uaual soybean flake preparation are: (1) drying to less than 3 percent moisture, (2) extraction with hot alcoholic solution recirculated from step 4, (3) cooling of separated extract, (4) recirculation of alcohol to step 2, (5) desolventizing of extracted flake, and (6) removal of residual alcohol from oil. This is, of course, an outline of the process and I do not wish to imply that the simplicity indicates any decrease in the technical skill required in any other solvent-extraction process.

Careful material and energy balances have shown that, on a theoretical basis, the cost in energy of this alcoholic extraction is three-fourths that of the hexane process. Practical design considerations indicate the cost of operation to be about the same as for the hexane process.

The process is safer, the products are better, there is a large series of new products, and alcohol is also a derived agricultural product.